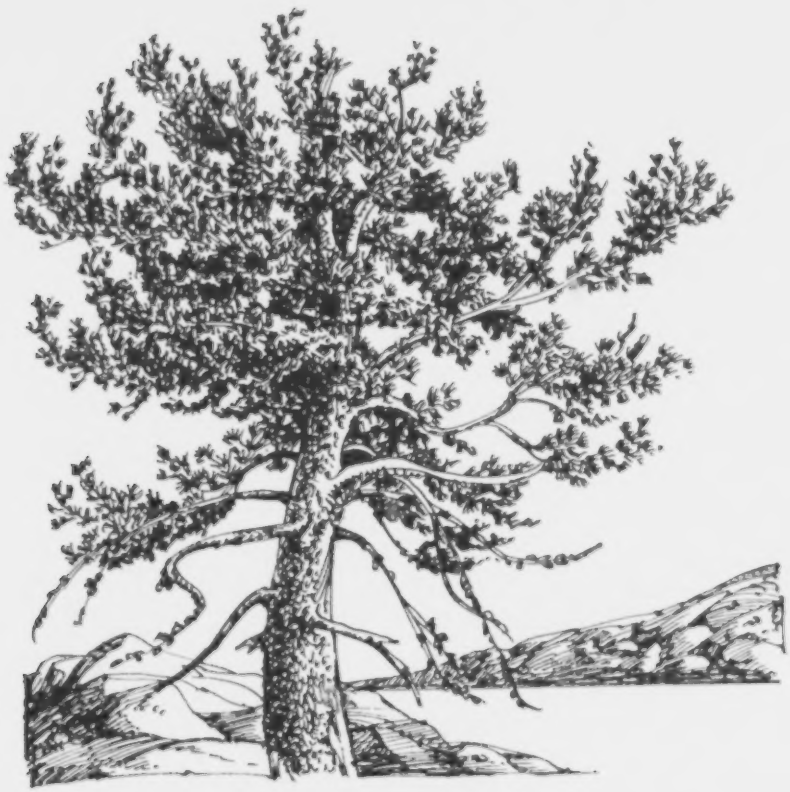
Status of the Limber Pine (*Pinus flexilis*) in Alberta



Fish & Wildlife Division

RESOURCE DATA AND SPECIES AT RISK SECTION

Alberta Wildlife Status Report No. 62

Alberta Conservation Association

Alberta

Status of the Limber Pine (*Pinus flexilis*) in Alberta

Prepared for:
Alberta Sustainable Resource Development (SRD)
Alberta Conservation Association (ACA)

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PREFACE

Every five years, the Fish and Wildlife Division of Alberta Sustainable Resource Development reviews the general status of wildlife species in Alberta. These overviews, which have been conducted in 1991 (*The Status of Alberta Wildlife*), 1996 (*The Status of Alberta Wildlife*), 2000 (*The General Status of Alberta Wild Species 2000*), and 2005 (*The General Status of Alberta Wild Species 2005*) assign individual species "ranks" that reflect the perceived level of risk to populations that occur in the province. Such designations are determined from extensive consultations with professional and amateur biologists, and from a variety of readily available sources of population data. A key objective of these reviews is to identify species that may be considered for more detailed status determinations.

The Alberta Wildlife Status Report Series is an extension of the general status exercise, and provides comprehensive current summaries of the biological status of selected wildlife species in Alberta. Priority is given to species that are *At Risk* or *May Be At Risk* in the province, that are of uncertain status (*Undetermined*), or that are considered to be at risk at a national level by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Reports in this series are published and distributed by the Alberta Conservation Association and the Fish and Wildlife Division of Alberta Sustainable Resource Development. They are intended to provide detailed and up-to-date information that will be useful to resource professionals for managing populations of species and their habitats in the province. The reports are also designed to provide current information that will assist Alberta's Endangered Species Conservation Committee in identifying species that may be formally designated as *Endangered* or *Threatened* under Alberta's *Wildlife Act*. To achieve these goals, the reports have been authored and/or reviewed by individuals with unique local expertise in the biology and management of each species.

EXECUTIVE SUMMARY

Limber pine (*Pinus flexilis*) is distributed from southwestern Alberta and southeastern British Columbia to northern Arizona and New Mexico and southern California. In Alberta it exists in disjunct stands, and plans for the detailed mapping of the location and boundaries of limber pine stands are underway. This report summarizes existing information on limber pine in Alberta to assist in assessing its status in the province.

In Alberta, the species is found in montane and lower subalpine areas on xeric-to-subxeric, exposed and wind-swept sites. It is a pioneer species and colonizes disturbed sites, and thrives in harsh environments. Its seeds are dispersed mainly by Clark's nutcracker (*Nucifraga columbiana*), and this mutualistic relationship is critical to the long-term viability of limber pine.

An invasive alien fungus, white pine blister rust (*Cronartium ribicola*), causes high mortality and is largely responsible for the decline of limber pine throughout most of its range in Alberta. High mortality coupled with often-poor regeneration provides a poor prognosis for limber pine.

ACKNOWLEDGEMENTS

The assistance of several people greatly aided the preparation of this report, and is gratefully acknowledged: Bev Wilson (Alberta Sustainable Resource Development, Forest Management Branch) provided data on the distribution of limber pine in Alberta; Cyndi Smith (Parks Canada, Waterton, AB) provided data on the distribution of limber pine and the impact of white pine blister rust in the national parks; Brian Klinkenberg (Department of Geography, University of British Columbia, Vancouver, BC) and Del Meidinger (B.C. Ministry of Forests and Range, Victoria, BC) provided distribution data for limber pine in BC; Roger Brett (Canadian Forest Service, Edmonton, AB) helped with production of maps; Ken Greenway (Alberta Sustainable Resource Development, Edmonton) provided information about regulations on harvesting of limber pine; and Dale Simpson (Canadian Forest Service, Fredericton, NB) provided information concerning optimal harvesting of limber pine cones. This report was greatly improved by comments made by Sue Peters (Alberta Conservation Association, Edmonton, AB) and Lisa Matthias (Alberta Sustainable Resource Development, Edmonton), Brendan Wilson (Selkirk College, Castlegar, BC), Peter Achuff (Parks Canada, Waterton) and Cyndi Smith.

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INTRODUCTION

Limber pine (*Pinus flexilis*) is one of five *Pinus* species native to Alberta. It is widely distributed throughout the western United States. In Canada, limber pine is found predominantly in Alberta, but there are a few small disjunct stands in the East Kootenays of southeastern British Columbia. In Alberta, limber pine is largely confined to the Montane Subregion of the Rocky Mountain Natural Region, including the Porcupine Hills. It is found mainly on ridge tops and slopes with southern or western exposures. The species is ranked S2/G5* by the Alberta Natural Heritage Information Centre (Gould 2006). The species has not been assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

This report summarizes current and historical information about limber pine in Alberta. This information will be used to assess the status of the species in Alberta and to guide the development of prospective management and conservation strategies.

HABITAT

The climate of the Montane Subregion results in cool summers; however, owing to warm Pacific air masses and frequent chinooks, this subregion has relatively warm winters, and is intermittently snow-free (Natural Regions Committee 2006). Microclimates are highly variable because of the variable terrain. North- and east-facing slopes tend to be cooler and more moist because they are more sheltered from direct sun and the prevailing winds. However, south- and west-facing slopes, where limber pine tends to predominate, receive more sunlight and are exposed to the drying influence of strong westerly winds, often resulting in significant moisture deficits. In the Montane Subregion, the mean annual temperature is 2.3°C, the mean July temperature is 13.9°C, and the mean January temperature is -10.0°C. The average number of growing degree days above 5°C is 708, and there is an average of 64 frost-free days per year. Average annual precipitation is 589 mm and the summer moisture index averages 2.7. Precipitation is generally lower in the northerly portion of the Montane Subregion. Soils in areas where limber pine grows are mainly Regisolics and Brunisolics (P. Achuff, pers. comm.). The Porcupine Hills, where large numbers of limber pine trees occur, are underlain by relatively flat-lying sedimentary rocks, often exposed in outcrops.

Limber pine grows on a variety of topographies, from gently rolling terrain to cliffs. It is most often found on rocky ridges and on steep rocky slopes, especially those with southern or western exposures, and can survive in extremely windswept and dry areas at both the lower and upper tree line. Often limber pine is the only tree species capable of growing on many of these sites. In the front ranges, limber pine tends to grow on scree slopes and rocky ridges where there is thin soil. In the foothills and Porcupine Hills, sites with limber pine generally have deeper soil, although many trees still grow on rocky outcrops. In the Kananaskis Valley, near the northern extent of its range, limber pine also occasionally grows in gravel creek beds (Webster and Johnson 2000). All of the growing sites for limber pine are xeric to sub-xeric because of the rapid run-off as a result of slope and coarse soils, exposure to strong winds and exposure to direct sunlight. Limber pine is also an effective colonizer of disturbed sites, and is usually the first tree to colonize burned sites because of rapid seed dispersal by nutcrackers and its high tolerance of harsh, xeric conditions (Steele 1990).

There is no information available about trends in limber pine habitat, likely because until recently there has been little interest in defining this type of habitat. However, throughout much of the geographic range of limber pine in Alberta

* See Appendix 1 for definitions of selected status designations.

there are areas that appear to contain suitable habitat (based on climatic and soil conditions and lack of competing tree species) but are not occupied or appear to be under-populated. Some of the areas in the Porcupine Hills with sparse limber pine populations were subjected to removal and burning of large numbers of limber pine infested by the mountain pine beetle (*Dendroctonus ponderosae*) in the late 1970s and early 1980s. These areas can potentially be repopulated with limber pine.

Plants that commonly co-occur with limber pine in the Montane Subregion are Engelmann spruce (*Picea engelmannii*) and lodgepole pine (*Pinus contorta*), and occasionally Douglas fir (*Pseudotsuga menziesii*) and white spruce (*Picea glauca*). Where limber pine occurs in the lower subalpine, it may co-occur with subalpine fir (*Abies lasiocarpa*), Engelmann spruce, and rarely whitebark pine (*Pinus albicaulis*). The most common shrubs associated with limber pine are common juniper (*Juniperus communis*), creeping juniper (*Juniperus horizontalis*), shrubby cinquefoil (*Potentilla fruticosa*) and bearberry (*Arctostaphylos uva-ursi*). Graminoids are very common on most sites in the foothills and Porcupine Hills, and in those areas limber pine often grows in open stands in what is essentially a grassland ecosystem (Achuff 1989; Archibald et al. 1996).

CONSERVATION BIOLOGY

Limber pine is a member of the family Pinaceae (Farrar 1995). The species is slow-growing and long-lived. In Alberta, the oldest recorded tree is 642 years, but 200-400 years-old trees are not uncommon in the northern part of the range (Webster and Johnson 2000). In the Porcupine Hills and further south, large old trees are now quite rare as they suffered high mortality from the mountain pine beetle during the last outbreak in the late 1970s and early 1980s (AFLW 1986). Limber pine is a short tree and rarely grows beyond 15 m in height, although diameter may be as great as 60 cm in very old trees (Farrar 1995). Because of the harsh growing conditions, limber pine often develops a bushy growth form as it ages. On mature trees, the trunk is short and stout, markedly tapered, crooked, and often branched. The crown is irregular and extends over most of the tree's length. Young branches are very flexible and can be severely bent without breaking. Old branches tend to droop with tips upturned. In severely windswept sites, limber pine often develops a "krummholz" growth form with stems bent and growing horizontally along the ground. Krummholz trees rarely extend above 2 m from the ground but stems may be greater than 20 cm thick and several metres long (D.W. Langor, pers. observ.). Roots of limber pine are known to be associated with a mycorrhizal fungus (*Gomphidius smithii*) (Trappe 1962), but it is not known how this association affects tree growth and survival.

It is reported that limber pine in the USA does not commence bearing cones until at least 50 years of age (Schoettle 2004); however, reproductive age has not been examined in Alberta. Although the relationship between limber pine age and reproductive output has not been examined, cones have been observed on the largest (i.e., oldest) trees in many stands in Alberta (D.W. Langor, unpubl. data). Limber pine is monoecious, with male and female strobili (flowers) borne separately on the same tree. As with most pines, female strobili dominate at the apical end of the main branches in the upper crown and male strobili predominate in the lower crown. Pollination by wind occurs in June and July, after which the cone scales close and the strobili begin to develop slowly (Steele 1990). Fertilization occurs the following spring or early summer, after which cones and seeds mature rapidly. As they mature, cones turn colour from green to light brown. In Alberta, cones mature in late August to early September. Large cone crops are produced every 2-4 years. In southern Alberta, large cone crops were observed in 2003 and 2006 (D.W. Langor, unpubl. data). The seeds are large and wingless

and readily drop from open cones over a 2-3 week period in late August and early September. Seeds typically fall within the drip line of the tree. Cones harvested from trees before seed embryos are mature will not result in viable seed. The embryo must be at least 90% of the length of the seed cavity upon harvesting to ensure viability (D. Simpson, pers. comm.).

Dispersal of limber pine seed is mainly accomplished by rodents and birds. Although red squirrels (*Tamiasciurus hudsonicus*) actively harvest limber pine cones, 80% of harvested cones are still green and the seed is not viable (Benkman et al. 1984). Thus, squirrels contribute little to dispersal. Small rodents such as mice (*Peromyscus*) and voles (*Microtus*) harvest seed that has fallen to the ground and often cache it; however, caches are usually close to the source tree and in locations not always amenable to good germination success (Benkman et al. 1984). The Clark's nutcracker (*Nucifraga columbiana*) is the most important user and efficient disseminator of limber pine seed (Tomback 1994). Nutcrackers harvest ripened seed from open cones in August and September and transport them, in mouth pouches located underneath their tongues, up to 22 km away (Vander Wall and Balda 1977; Tomback and Kramer 1980). A bird can carry up to 125 seeds per trip. Seeds are buried in the ground (2-3 cm deep) in separate caches of 1-5 seeds. Many of these caches are not later utilized by the birds. An American study (Lanner and Vander Wall 1980) indicated that nutcrackers cached in one year about 30 000 limber pine seeds per hectare. Preferred cache sites are windswept ridges and southerly aspects where snow does not accumulate and the ground is exposed in early spring. Thus, the location of most limber pine stands likely reflects the site preferences of dispersal agents, mainly nutcrackers, rather than those of the pine, since its only other means of dispersal is gravity. Seeds in caches remain viable for up to two years (Webster 1998). In the Kananaskis Valley, limber pine populations showed continuous recruitment over 100 years, including rapid recruitment in populations exterminated by fire and isolated by several kilometres from the nearest source of limber pine seed (Webster and Johnson 2000). The interaction between limber pine and Clark's nutcracker is highly evolved and important for the survival and well-being of both species (Tomback and Linhart 1990).

Limber pine seeds also provide an important source of nutrition for black bears (*Ursus americanus*) and grizzly bears (*Ursus arctos*) (McCutchen 1996). Seeds have been found in the scat of bears in Waterton Lakes National Park (WLNP) and the Porcupine Hills, where many limber pine are short enough that bears can access cones without having to climb trees or rely on middens and caches (Kendall 2001).

As a result of the seed-caching behaviour of nutcrackers, it is common for limber pine throughout its range to grow in clusters containing 2-7 stems (usually 2-3 stems). Where studied in detail in Colorado, limber pine clusters (versus single stems) constituted 5% to 77% (average is 20%) of "tree sites" in a stand (Woodmansee 1977; Carsey and Tomback 1994). When the genotype of each trunk within a cluster was examined, 17.6% of clumps contained more than one individual (maximum of four individuals) (Schuster and Mitton 1991). In another study, 79% of tree clumps contained multiple individuals (Linhart and Tomback 1985). Clearly, this situation arises as a result of multiple individuals germinating within each seed cache, and high tolerance of crowding by seedlings. On very harsh sites, including early successional environments, tree clusters may provide more efficient nutrient acquisition or mutual protection from strong winds (Donnegan and Rebertus 1999). However, genets (a population of plants growing in tight proximity that are all genetically identical) growing in clusters may be less fit than solitary genets with respect to tree architecture and reproductive success (Feldman et al. 1999). Multi-trunk pines

appear to be strongly disadvantaged during mid-succession when crowded and shaded by spruce and fir (Donnegan and Rebertus 1999). In the evolution of the mutualism between limber pine and Clark's nutcracker, the costs of multi-trunk forms are clearly outweighed by the benefits of nutcracker-mediated seed dispersal (Feldman et al. 1999).

Limber pine exists in discrete local populations that are subject to recurrent extirpation by wildfire. Although local populations also show somewhat synchronous regional mortality (e.g., to stochastic weather events), this is not severe enough to cause extirpation of all populations within a region. When there is catastrophic mortality or extirpation, recolonization is rapid because of seed dispersal by Clark's nutcracker. Open canopy limber pine stands are always available for recruitment because tree density is low and the forest floor contains much exposed mineral soil and scree, both of which are good recruitment surfaces (Webster and Johnson 2000).

Limber pine is relatively intolerant of shade and is, therefore, seral to other co-occurring tree species on all but the most severe (xeric) sites. Limber pine acts as a pioneer species following site disturbance and ameliorates conditions for other tree species by providing shade and protection from wind (Baumeister and Callaway 2006). Rates of succession are influenced by site conditions such as slope, aspect, ground cover, wind exposure, and proximity of seed sources (Rebertus et al. 1991), and can vary two- or threefold over relatively short distances (Donnegan and Rebertus 1999). Replacement on xeric sites in the subalpine Colorado Front Range may take more than 500 years, but given the likelihood of stand-replacing fires every 200-400 years (Peet 1981), complete replacement may not occur on most sites and limber pine represents a climax community (McCune 1988). On less xeric sites stand replacement occurs more quickly as limber pine become overtopped and shaded, mainly by spruce (*Picea*) and fir (*Abies*), resulting in pine mortality (Rebertus et al. 1991; Donnegan and Rebertus 1999).

DISTRIBUTION

The current distribution of limber pine has been markedly influenced by Pleistocene glaciation patterns and subsequent dispersal from numerous glacial refugia east of the Rocky Mountains in Colorado and Kansas, in the Great Basin, in Fremont Co., Colorado and in Bighorn Co., Wyoming (Mitton et al. 2000; Jorgensen et al. 2002). Current populations in Canada must have been colonized by seeds from distant populations dispersed by Clark's nutcracker following glacial retreat. Each population must have been established by a relatively large number of seeds because genetic diversity is not greatly reduced in this region compared to more southern populations more closely located to putative refugia (Jorgensen et al. 2002). Genetic data for current populations in Canada suggest colonization from several glacial refugia in the United States (Mitton et al. 2000; Jorgensen et al. 2002).

1. Alberta. – In Alberta, limber pine is found primarily in the Montane Natural Subregion, which encompasses the eastern slopes of the front ranges of the Rocky Mountains and the foothills of the southwest (Figure 1). There are a few isolated occurrences of limber pine on the western edge of the Foothills Parkland Natural Subregion. Limber pine also occurs in the transition zone between the Montane and Subalpine Subregions and sometimes extends into the lower elevations of the Subalpine Subregion on the east slopes. On the front ranges limber pine is found at altitudes of 1020 m to 1970 m (mean of 1640 m), whereas in the foothills and Porcupine Hills it grows at altitudes of 1360 m to 1660 m.

Limber pine ranges along the eastern slopes and foothills of the Rocky Mountains from the border with Montana as far north as Windy

Figure 1: The distribution of limber pine in Alberta. Data at the "Limber pine research sites" were collected by the Canadian Forest Service (CFS; Edmonton) and Parks Canada (Waterton Lakes National Park; WLNP). "Other inventory data" includes the Alberta Vegetation Inventory and other polygons of inventory data collected by CFS.

Point and Abraham Lake (west of Nordegg), at 52.25 degrees latitude. Substantial stands also occur throughout the Porcupine Hills. The distribution of this species is rather disjunct throughout its Canadian range, with distance between disjunct stands increasing with increased latitude and altitude. Although it is possible to delimit the extent of occurrence of limber pine in Alberta (Figure 1), the boundaries of disjunct stands have not been well mapped over most of the range. Figure 1 includes points to indicate location of stands from which data or specimens have been historically collected. Also, some AVI inventory data are available and have been included in Figure 1; however, some of these stands, especially those at higher elevations, need to be verified for presence of limber pine. Whitebark pine, which also grows in subalpine stands, is sometimes confused with limber pine, resulting in misidentifications in inventory records. Detailed mapping of limber pine distribution in Alberta is clearly needed.

The extent of occurrence (EO) of limber pine in Alberta is ca. 25 300 km^2 using a convex hull polygon, and could be as low as 16 000 km^2 if disjunctions in the overall distribution are excluded. The area of occupancy (AO) was estimated from observations of survey crews from the Canadian Forest Service to be less than 0.5% of the EO, or less than 80 km^2. The estimate of AO increases to about 1420 km^2 when a 2-km by 2-km grid is overlaid on all known locations. Two groups of stands at the northern extent of the range, one southwest of Nordegg and one west of Sundre are separated by about 50 km from each other and from the main distribution of limber pine further south. The genetic structure of limber pine in Alberta has been too poorly studied to date to designate populations; however, there is ongoing work at the Canadian Forest Service and University of Guelph to genetically characterize limber pine in Alberta and BC (D.W. Langor, unpubl. data). The limber pine at Windy Point (i.e., the northernmost stand of this species, located southwest of Nordegg) is genetically unique based on mitochondrial DNA data (Mitton et al. 2000). It is unknown whether other stands of limber pine in this discrete cluster (Figure 1) share these unique genetic characteristics.

2. Other Areas. – In Canada, limber pine is also found in a few small, isolated pockets in southeastern British Columbia, as far north as the vicinity of Golden and as far south as Columbia Lake (near Canal Flats) (Figure 1; Steele 1990). The vast majority of limber pine occurs in the United States, ranging from Montana and Idaho south to northern New Mexico and Arizona and southern California (Figure 2). Montana, Idaho, Wyoming, Colorado, Utah and Nevada have the largest amount of limber pine. Notable outlier populations occur in western portions of North Dakota, South Dakota and Nebraska, and in northeastern Oregon and southwestern California. The species ranges in latitude from 33 to 49 degrees, and altitude from 870 m in North Dakota to greater than 3400 m in Colorado (Steele 1990).

POPULATION SIZE AND TRENDS

1. Alberta. – Pollen records indicate that soft pines (subgenus *Strobus*), mainly limber pine, have existed in the foothills and eastern ranges of southwestern Alberta for more than 10 000 years (MacDonald 1989). The current total Alberta population of limber pine is not known; however, the number of trees can likely be measured in the millions. Few of the existing stands have been mapped. In the Kananaskis Valley, the density of limber pine trees with a basal diameter greater than 5 cm ranges from 52 000 to 174 000 stems per km^2, and averaged 95 500 stems per km^2 over the 13 stands assessed (Webster and Johnson 2000). In Waterton Lakes, Banff and Yoho National Parks, the density of limber pine (trees, seedlings and krummholz forms) ranged from 26 000 to 171 000 stems per km^2, and averaged 71 300 stems per km^2 over the 34 plots assessed (C.M. Smith, unpubl. data). The density of trees (greater than 1.3 m tall), krummholz forms and

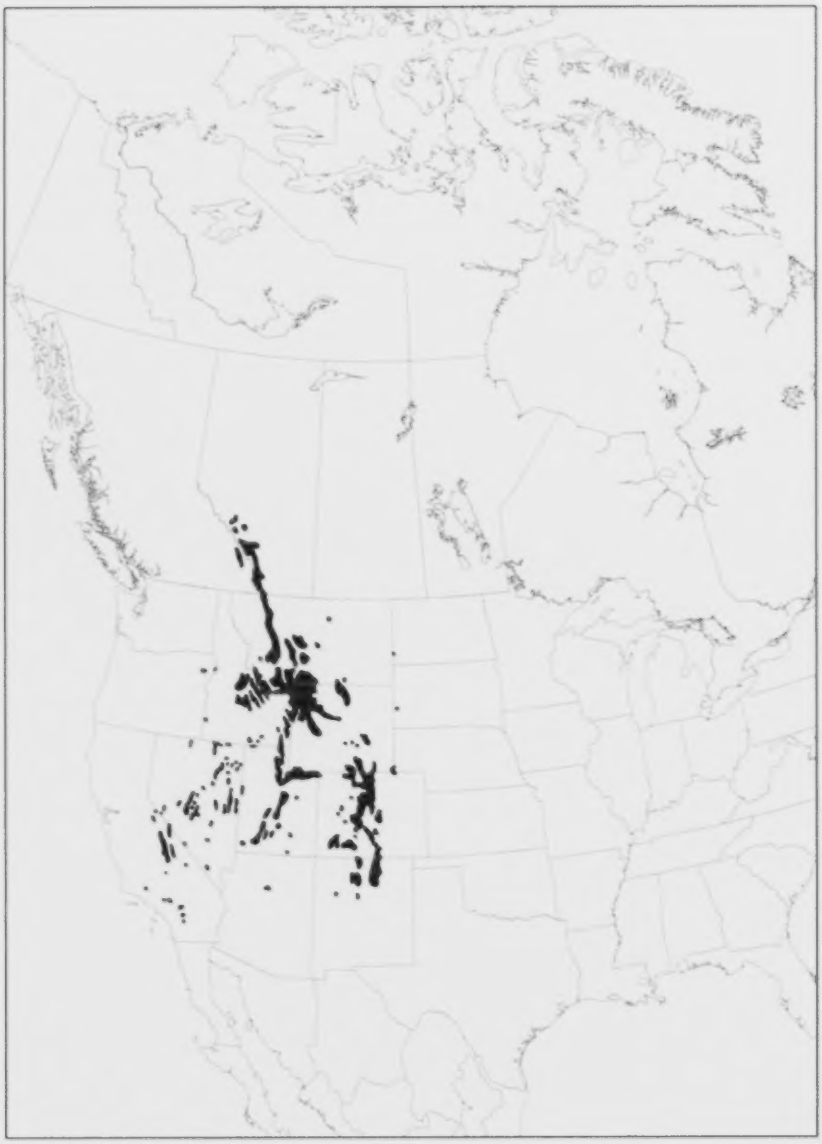

Figure 2. The distribution of limber pine in North America [redrawn from Critchfield and Little (1966)].

seedlings average 48 500, 18 800 and 11 100 stems per km^2, respectively. As the stem density from the national parks is the lower of the two estimates, this may be used to obtain a minimal population estimate for Alberta of less than 5 704 000 individuals (71 300 stems per km^2 multiplied by the estimated AO of less than 80 km^2). As trees under 10 cm diameter at breast height (dbh) are not reproductively mature and krummholz forms contribute little to overall reproduction (D. Langor, pers. observ.), based on size class distributions, it is estimated that about 50% of individuals classified as trees are of reproductive age. Thus, based on the stem density estimates from the national parks, fewer than 24 250 individuals per km^2 are of reproductive age. The estimated provincial population of mature individuals is therefore 1 940 000 (24 250 individuals/km^2 multiplied by 80 km^2).

Populations of limber pine in Alberta are declining, largely as a result of mortality caused by an invasive alien fungus, white pine blister rust (WPBR; *Cronartium ribicola*) (D.W. Langor and C.M. Smith, unpubl. data). This fungus infects the bark on tree stems and branches, creating cankers and destroying the conductive tissue. Stem infections often result in tree death. Surveys throughout the range of limber pine in Alberta in 2004-2005 (D.W. Langor and C.M. Smith, unpubl. data) found that the average mortality throughout Alberta was more than 27%. Mortality ranged from 49% in WLNP to 35% in the Porcupine Hills. North of the Porcupine Hills, mortality was much lower, ranging from 7% to 17% in different stands. Although it is not possible to assess cause of mortality for many trees, it is thought that WPBR is likely the main mortality agent. The estimated proportion of living trees infected by WPBR is very high (54% - 62%) throughout most of southern Alberta, and at least one-third of infected trees are declining in health. The percent of infected trees is much lower (0% - 2%) in the northern part of limber pine range in Alberta.

The rate of limber pine decline can be calculated for a few stands in WLNP and the Porcupine Hills (Whaleback Region) by comparing data collected by Kate Kendall in 1996 (Kendall et al. 1996) to that collected in 2004. In WLNP, limber pine mortality increased from 46% in 1996 to 56% in 2004. The proportion of living trees with WPBR infection decreased from 92% in 1996 to 82% in 2004. In the Porcupine Hills, limber pine mortality increased from 14% in 1996 to 43% in 2004, and the proportion of living trees with WPBR infection increased from 55% in 1996 to 65% in 2004.

The low regeneration of limber pine in many severely infected stands means that mortality outpaces recruitment, resulting in population decline in most stands in the southern half of the range. WPBR entered Alberta from the south (first record from limber pine in Alberta from Table Mountain in 1952 [Bourchier 1952]) and has subsequently moved northward, so it is not surprising to see a north-south trend in severity. Clearly this fungus (which has no known treatment) will continue to exert a strong negative influence on limber pine population sizes in Alberta, and this impact is gradually moving northward throughout the range of limber pine.

2. ***Other Areas.*** – In BC there are a few isolated and small pockets of limber pine, but estimates of population size have not been made. At least two of those populations (near Golden) have WPBR infections, but mortality is very low (ca. 1.3%) and regeneration is good (C.M. Smith, unpubl. data).

The vast majority of limber pine is found in the United States, and that is where most of the genetic diversity resides (Mitton et al. 2000). Estimates of population sizes do not appear to exist. Population trends vary according to region. In northwestern and central Montana, limber pine is severely impacted by WPBR and is clearly in decline (Jackson and Lockman 2003). The impact does not appear to be as great

elsewhere. There are no published reports of population trends for limber pine in the United States.

LIMITING FACTORS

Most of the limiting factors for limber pine in Alberta are natural and not intentionally human-caused.

1. Insects and diseases. – The main limiting factor for limber pine, especially in the southern half of its range in Alberta, is WPBR. As WPBR is present in almost every limber pine stand surveyed in Alberta, and as it can be expected that the incidence and impact of WPBR in each infected stand can increase rapidly, the prognosis for limber pine in Alberta is not good. Ongoing work (D.W. Langor, unpubl. data) is assessing the impact of WPBR on genetic diversity of limber pine, as well as impacts on seed production and quality. Furthermore, it has recently been discovered that WPBR naturally hybridizes with the comandra blister rust (*Cronartium comandrae*), a native rust on hard pines, and that hybrids occur on limber pine (Joly et al. 2006). This may have implications for the pathogenicity of rusts on limber pine that is being explored further.

The mountain pine beetle (MPB; *Dendroctonus ponderosae*) can kill and breed in limber pine (Langor 1989; Langor et al. 1990). During the early 1980s, the MPB killed large numbers of limber pine in southwestern Alberta. Over the winters of 1983-84 and 1984-85, almost 40,000 MPB-infested limber pines were cut and burned north of Route 3 in Alberta, especially in the Porcupine Hills (AFLW 1986). Additional thousands of limber pine were killed by the MPB but not treated. As the MPB tends to first attack the largest trees in a stand, the result of the last outbreak in Alberta was that a large proportion of the oldest trees were lost throughout the Porcupine Hills and south to Waterton Lakes National Park. Currently the MPB is again expanding its populations and range in southwestern Alberta (Alberta Sustainable Resource Development 2005). Although there are no reports yet of limber pine being attacked, there is a significant risk. Trees already weakened by WPBR may be more susceptible to MPB (Kegley 2006).

A parasitic vascular plant, limber pine dwarf mistletoe (*Arceuthobium cyanocarpum*), has caused high mortality of limber pine in some Rocky Mountain States (Hawksworth et al. 2002). Although the mistletoe is not yet reported from Canada, it is close to the Canadian border in Montana (Taylor and Mathiason 1999). Similarly, the fungus *Dothistroma septospora* causes a needle blight in limber pine in Montana, that has caused significant mortality (Taylor and Walla 1999; Jackson and Lockman 2003) but has not yet been recorded from Alberta. If the distribution of these (and other) pest species are limited by climate, they may eventually invade Alberta as the climate warms.

Several insects feed on the seeds and cones of limber pine, including the ponderosa pine coneworm (*Dioryctria auranticella*) and the western conifer seed bug (*Leptoglossus occidentalis*) (Schoettle and Negron 2001). The seed bug is known from Alberta but there is no evidence of significant seed predation.

2. Vertebrate herbivores. – Seed crops of limber pine are significantly affected by mammals and birds. Clark's nutcracker, red squirrels and other vertebrate seed predators take the majority of the seed crop (Tomback and Kramer 1980). Although the benefits of seed dispersal by nutcrackers clearly outweigh seed consumption, the seed-eating activities of mammals are clearly detrimental. Red squirrels are an important constraint to seed dispersal. They harvest cones before seed is viable so cached seed does not germinate. In Arizona over 80% of limber pine cones may be harvested by squirrels (Benkman et al. 1984), but there are no estimates for Alberta.

Porcupines (*Erethizon dorsatum*) also strip bark from the stems of limber pine in southwestern Alberta. In cases where sufficient bark is removed, stems and branches may become girdled and die (Harder 1980).

3. ***Cattle grazing.*** – Throughout the Montane Subregion limber pine usually grows in open stands on what are otherwise grasslands. Many of these stands are on private land that is used for cattle ranching. As well, cattle grazing leases are in effect for many parts of the Green Zone, especially in the Porcupine Hills. As a result, most limber pine stands in the Montane Subregion have regularly experienced cattle grazing. Although there are no data to indicate that this grazing negatively affects limber pine, it is possible that regeneration may be affected. This is a potential limiting factor that requires further study.

4. ***Seed dispersal agents.*** – The heavy reliance of limber pine upon Clark's nutcracker for long distance seed dispersal and for colonization of newly disturbed sites means that the viability of limber pine is tightly linked to the viability of the nutcracker (Blouin 2004). In 2005, the general status of Clark's nutcracker in Alberta was ranked as *Sensitive* (up from *Secure* in 2000), because of its dependency on declining species such as limber pine and whitebark pine (Alberta Sustainable Resource Development 2007). It may also be susceptible to the West Nile virus (Blouin 2004).

5. ***Climate change.*** – As limber pine is very tolerant of dry conditions and has evolved to persist in harsh habitats, it may be expected that increased temperatures and decreased moisture associated with climate change will not affect limber pine as much as other less tolerant tree species inhabiting the montane areas of southwestern Alberta. It also may be that the lowered ability of some tree species to grow under climate change scenarios may increase the temporal persistence of limber pine by slowing or eliminating succession. Overall, it may be expected that climate change may promote geographic range extension of limber pine; however, this may be offset by the impact of other limiting factors.

6. ***Wildfire.*** – Fire appears to be the primary means of causing local extinction of limber pine, but it rarely does because trees are scattered and often found in areas where there is little fuel (Webster and Johnson 2000). Also, after a fire, the Clark's nutcracker quickly uses burned sites for seed caching, thereby contributing to rapid regeneration (Webster and Johnson 2000). If anything, declining incidence of fire as a result of effective fire management may be more of a limiting factor for limber pine. Fire can benefit limber pine in mixed stands by setting back succession, thereby favouring early colonizers such as limber pine. If wildfires become more frequent and extensive as a result of climate change, limber pine may benefit, but only if the fire return interval is longer than the age of limber pine reproductive maturity, and if the size of burned areas is sufficiently small to be fully utilized for seed caching by Clark's nutcracker.

STATUS DESIGNATIONS*

1. ***Alberta.*** – Limber pine is not listed under Alberta's *Wildlife Act*. The Alberta Natural Heritage Information Centre (ANHIC) ranks limber pine as S2 (Gould 2006). Beardmore et al. (2006) lists limber pine as a species that is in need of conservation in Canada. The general status of limber pine is *May Be At Risk* because of extensive mortality from white-pine blister rust within parts of its Alberta range, as well as additional mortality and risk from mountain pine beetle outbreaks (Alberta Sustainable Resource Development 2007).

2. ***Other Areas.*** – The global status for limber pine is G5, and the status was last

* See Appendix 1 for definitions of selected status designations.

reviewed in October 1984 (NatureServe 2006). The national status for limber pine in Canada is N3/N4, and in the United States is N5 (NatureServe 2006). Beardmore et al. (2006) lists limber pine as a species that is in need of conservation in Canada. In British Columbia, limber pine is ranked S3/S4 and the list status is yellow, which means that the species is apparently secure and not at risk of extinction (B.C. Conservation Data Centre 2006). In the United States, limber pine is ranked S1 in South Dakota, North Dakota and Nebraska, S4 in Oregon, and S5 in Wyoming; the other states in which limber pine occurs have not ranked the species (NatureServe 2006).

RECENT MANAGEMENT IN ALBERTA

In Alberta there are no regulations against harvesting of limber pine (K. Greenway, pers. Comm.). In WLNP, an experiment was recently initiated to assess the survival of limber pine seeds and seedlings (Poll et al. 2006).

SYNTHESIS

Assessment of the status of limber pine requires detailed information on its distribution and population levels. Although the general distribution of limber pine in Alberta is known, the boundaries of the many disjunct stands have not been mapped. As well, tree densities have not been estimated for most regions of Alberta. Future work should be focused on delimiting limber pine distribution and estimating population sizes.

Limber pine still exists in many stands in Alberta, and its numbers can likely be measured in the millions. However, the significant and growing mortality caused by WPBR, commonly coupled with poor regeneration, has caused a steep downward trend in many (and probably most) limber pine stands in Alberta. The fact that WPBR is present in almost all stands of limber pine means that the severe impacts already observed in the southern half of the range of limber pine in Alberta will likely eventually be experienced throughout the range. Monitoring of limber pine health should be periodically implemented to assess trends and rates of change.

The apparent association of low regeneration of limber pine with severe WPBR incidence needs detailed investigation to ascertain whether this is a cause-effect relationship. As the most severely infected stands occur mainly in montane areas where cattle are often present in limber pine stands, it is hypothesized that grazing activity is also linked to poor regeneration success.

Understanding of the genetic structure of limber pine in Alberta will provide some guidance for management. Identification of genetically unique populations can identify priorities for application of conservation measures and can direct seed collection for *in vitro* conservation. Ongoing genetics work will contribute towards this, but this work will have to be expanded to include more disjunct northern populations that have the highest probability of having a unique genetic profile.

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Appendix 1. Definitions of selected legal and protective designations.

A. The General Status of Alberta Wild Species 2005 (after Alberta Sustainable Resource Development 2007)

2005 Rank	1996 Rank	Definitions
At Risk	Red	Any species known to be *At Risk* after formal detailed status assessment and designation as *Endangered* or *Threatened* in Alberta.
May Be At Risk	Blue	Any species that may be at risk of extinction or extirpation, and is therefore a candidate for detailed risk assessment.
Sensitive	Yellow	Any species that is not at risk of extinction or extirpation but may require special attention or protection to prevent it from becoming at risk.
Secure	Green	Any species that is not *At Risk*, *May Be At Risk* or *Sensitive*.
Undetermined	Status Undetermined	Any species for which insufficient information, knowledge or data is available to reliably evaluate its general status.
Not Assessed	n/a	Any species that has not been examined during this exercise.
Exotic/Alien	n/a	Any species that has been introduced as a result of human activities.
Extirpated/Extinct	n/a	Any species no longer thought to be present in Alberta (*Extirpated*) or no longer believed to be present anywhere in the world (*Extinct*).
Accidental/Vagrant	n/a	Any species occurring infrequently and unpredictably in Alberta, i.e., outside its usual range.

B. Alberta Wildlife Act/Regulation

Species designated as Endangered under Alberta's *Wildlife Act* include those listed as *Endangered* or *Threatened* in the Wildlife Regulation.

Endangered	A species whose present existence in Alberta is in danger of extinction within the next decade.
Threatened	A species that is likely to become endangered if the factors causing its vulnerability are not reversed.

C. Committee on the Status of Endangered Wildlife in Canada (after COSEWIC 2006)

Extinct	A species that no longer exists.
Extirpated	A species that no longer exists in the wild in Canada, but occurs elsewhere.
Endangered	A species facing imminent extirpation or extinction.
Threatened	A species that is likely to become endangered if limiting factors are not reversed.
Special Concern	A species that may become threatened or endangered because of a combination of biological characteristics and identified threats.
Not at Risk	A species that has been evaluated and found to be not at risk given current circumstances.
Data Deficient	A category that applies when the available information is insufficient to a) resolve a species' eligiblity for assessment or b) permit assessment of a species/ risk of extinction

Appendix 1 continued.

D. Heritage Status Ranks: Global (G), National (N), Sub-National (S) (after Alberta Natural Heritage Information Centre 2006, NatureServe 2006)

G1/N1/S1	5 or fewer occurrences or only a few remaining individuals. May be especially vulnerable to extirpation because of some factor of its biology.
G2/N2/S2	6 to 20 or fewer occurrences or with many individuals in fewer locations. May be especially vulnerable to extirpation because of some factor of its biology.
G3/N3/S3	21 to 100 occurrences; may be rare and local throughout its range, or in a restricted range (may be abundant in some locations). May be susceptible to extirpation because of large-scale disturbances.
G4/N4/S4	Typically > 100 occurrences. Apparently secure.
G5/N5/S5	Typically > 100 occurrences. Demonstrably secure.
GX/NX/SX	Believed to be extinct or extirpated; historical records only.
GH/NH/SH	Historically known; may be relocated in the future.
G?/N?/S?	Not yet ranked, or rank tentatively assigned.

E. United States Endangered Species Act (after National Research Council 1995)

Endangered	Any species which is in danger of extinction throughout all or a significant portion of its range.
Threatened	Any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

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